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## Original Article

## Ductus venosus Doppler velocimetry in normal pregnancies from 11 to 13 + 6 weeks' gestation—A Taiwanese study

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## Abstract

**Background:** To investigate flow in the ductus venosus at 11–13 + 6 weeks of gestation in women with normal pregnancies in the Taiwanese population.

**Methods:** Two hundred and fifty-two normal singleton pregnancies with gestational ages ranging from 11 to 13 + 6 weeks were examined in this study. The pulsatility index for veins (PIV), resistance index (RI), peak velocity during ventricular systole (S-wave), and peak velocity during ventricular diastole (D-wave) were recorded from the ductus venosus.

**Results:** We analyzed 252 participants who all fulfilled the inclusion and exclusion criteria of our study. The mean maternal age was 31 (range 19–45 years), with a corresponding gestational age of 12 + 4 weeks (range 11–13 + 6). No significant change was found in the vascular indices as gestational age increased for the S-wave (S-wave = 1.4214 (GA) + 17.448,  $r = 0.09$ ,  $P = 0.154$ ), PIV (PIV =  $-0.0358$  (GA) + 1.4143,  $r = -0.05$ ,  $P = 0.378$ ) and RI (RI =  $-0.035$  (GA) + 1.1478,  $r = -0.064$ ,  $P = 0.468$ ). In contrast, the D-wave behaved differently from the other variables. There was a significant increase ( $r = 0.155$ ,  $P = 0.013$ ) in the D-wave with gestational age (D-wave = 1.4896 (GA) – 7.1547).

**Conclusion:** D-wave velocity in the ductus venosus increased with gestational age. S-wave peak velocity showed an increasing trend and PIV showed a decreasing trend with gestational age, but they did not reach statistical significance.

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**Keywords:** D-wave; diastolic wave velocity; ductus venosus; fetal color Doppler ultrasound; NT; nuchal translucency; PIV; pulsatility index for veins; RI; resistance index; S-wave; systolic wave velocity

## 1. Introduction

The sphincter-like ductus venosus (DV) is an important regulator of fetal circulation. It carries the oxygenated blood from the umbilical vein to the inferior vena cava and foramen ovale, thus bypassing the hepatic circulation. Highly oxygenated

blood passes through the right atrium and goes to the left atrium to perfuse the fetal brain and trunk.<sup>1–3</sup>

Doppler measurements of the DV have become important in monitoring the fetus in cases of intrauterine growth restriction<sup>4–6</sup> and cardiac defects.<sup>7–9</sup> The analysis of the DV has also been used to identify fetuses at risk of acidemia and perinatal death.<sup>4,6</sup> An abnormal DV blood flow velocity waveform is also associated with fetal anemia and twin-to-twin transfusion syndrome.<sup>10</sup> Recent studies on the A-wave of the DV have also demonstrated the importance of the ductus venosus in first-trimester screening for fetal chromosomal abnormalities.<sup>11,12</sup>

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Combined with nuchal translucency and fetal nasal bone, DV further augments the power of Down's syndrome screening. However, some studies have shown the influence of ethnicity and the need for correction of biochemical and ultrasound markers of chromosomal anomalies in the first trimester for different ethnic groups.<sup>13–16</sup> Those studies focused on nuchal translucency and fetal nasal bone as ultrasound markers, but did not include DV. Hence, it is important to establish a database for a Chinese population in Taiwan. The aim of our study was to investigate ductus venosus flow indices at 11 to 13 + 6 weeks of gestation in a normal pregnancy in the Taiwanese population and to compare our results with previously published reports.

## 2. Methods

### 2.1. Patient population

A total of Two hundred and fifty-two women with normal singleton pregnancy between 11 and 13 + 6 weeks' gestation were examined in this study. Fetal age was estimated from the last menstrual period, and it was confirmed by ultrasonographic measurement of the crown-rump length. The following women were excluded from our study: (1) women with gestational diabetes, preterm labor, antepartum congenital abnormalities, and maternal systemic disease; (2) women on a regimen of tocolytic and antihypertensive agents; and (3) women who were absent during the patient follow-up process. Hospital medical records were reviewed to confirm pregnancy outcomes, and newborns with abnormal karyotypes or major structural abnormalities were also excluded. The study was approved by the Institutional Review Board at Taipei Veterans General Hospital in Taipei, Taiwan, and each patient participating in the study provided a signed and approved informed consent form.

### 2.2. Ultrasonography

All ultrasonography procedures were performed using a Voluson 730 ultrasound machine (GE Healthcare, Milwaukee, WI, USA) equipped with a 4- to 8-MHz transducer, and color Doppler was used for evaluation of the DV. The flow velocities from the DV were identified using color Doppler imaging in a right ventral midsagittal plane (Fig. 1A). The pulsed Doppler gate was placed in the distal portion of the umbilical sinus (Fig. 1B). Care was taken to avoid contamination from the umbilical vein, left hepatic vein, and inferior vena cava.<sup>13</sup> When the typical DV waveform was obtained, at least three consecutive waveforms were recorded with insonation angle  $\leq 30^\circ$ . The following variables were measured: S-wave, D-wave, pulsatility index for veins (PIV), and resistance index (RI).

### 2.3. Statistical analysis

Data were collected in an Excel spreadsheet (Microsoft, Redmond, WA, USA) and analyzed using the software SPSS for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA).

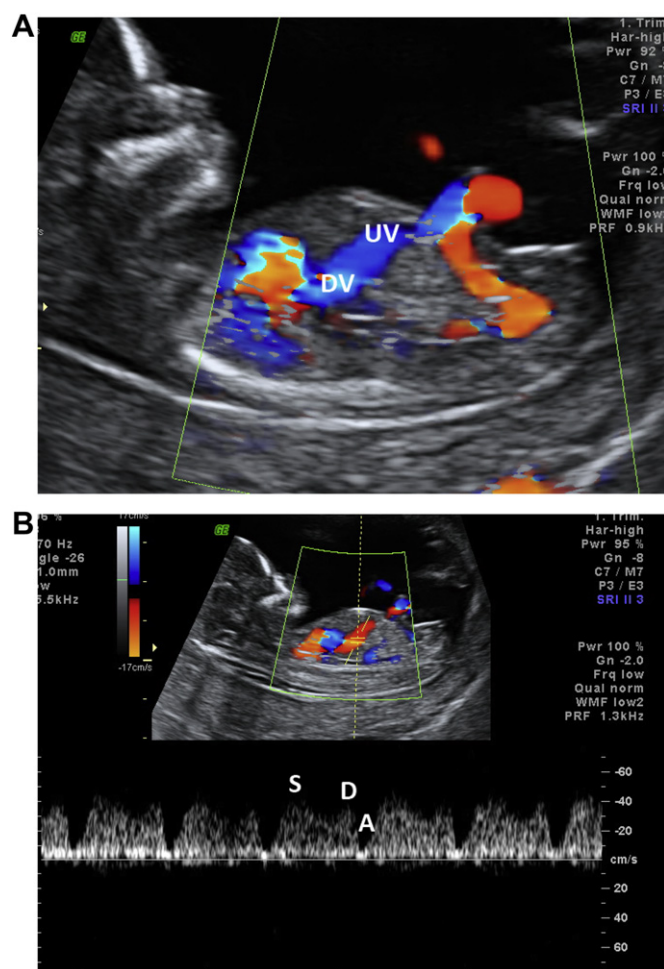


Fig. 1. (A) DV with color Doppler in a right ventral midsagittal plane; (B) pulsed Doppler gate was placed in the distal portion of the umbilical sinus. DV = ductus venosus.

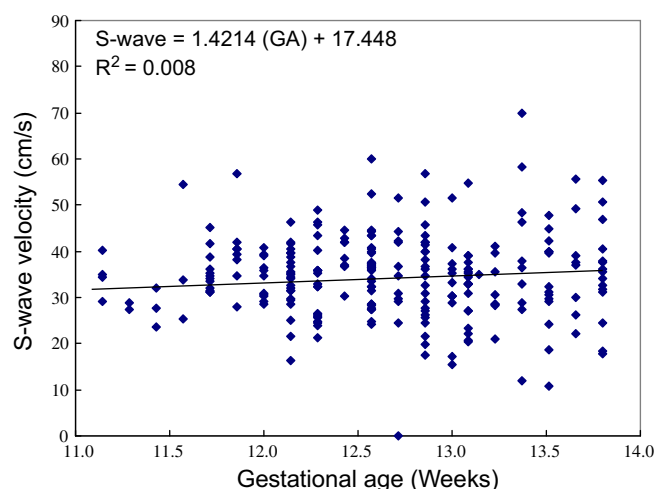


Fig. 2. Individual values for the peak systolic velocity (S-wave) in the ductus venosus in normal pregnancy [ $S\text{-wave} = 1.4214 (GA) + 17.448$ ,  $r = 0.09$ ,  $p = 0.154$ ]. GA = gestational age (wk).

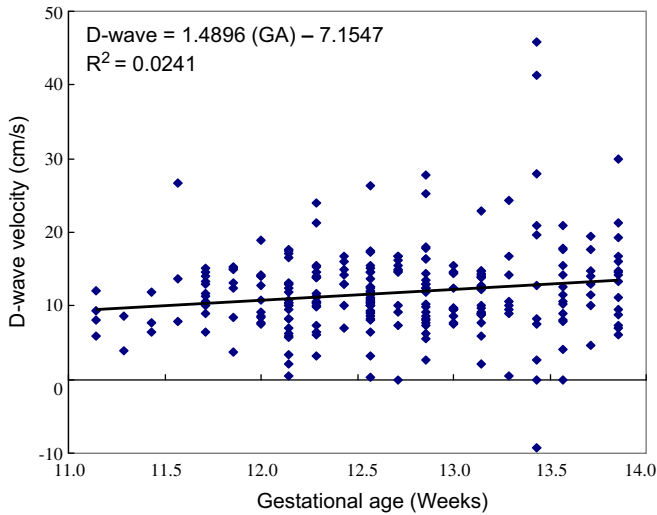


Fig. 3. Individual values for the peak diastolic velocity (D-wave) in the ductus venosus in normal pregnancy [D-wave =  $1.4896 \text{ (GA)} - 7.1547$ ,  $r = 0.155$ ,  $p = 0.013$ ]. GA = gestational age (wk).

The relationships between the Doppler variables and gestational ages were evaluated by regression analyses. Pearson's correlation coefficient was used to assess the degree of correlation between variables (Fig. 1).

### 3. Results

A total of Two hundred and fifty-two eligible participants fulfilling the inclusion and exclusion criteria were analyzed. The mean maternal age was 31 (range, 19–45 years), corresponding to a gestational age of  $12 \pm 4$  weeks (range, 11 to  $13 \pm 6$  weeks). Reference curves for the ductus venosus DV Doppler variables were plotted (Figs. 2–5). No significant change was found in the vascular indices with gestational age (GA) for the S-wave, PIV, and the RI. Nevertheless, the D-wave behaved differently from the other variables. There was

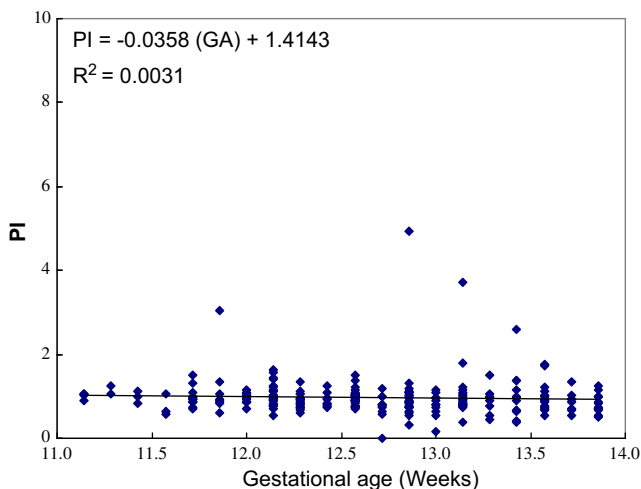


Fig. 4. Individual values for PIV in the ductus venosus in normal pregnancy [PIV =  $-0.0358 \text{ (GA)} + 1.4143$ ,  $r = -0.05$ ,  $p = 0.378$ ]. GA = gestational age (wk); PIV = pulsatility index for veins.

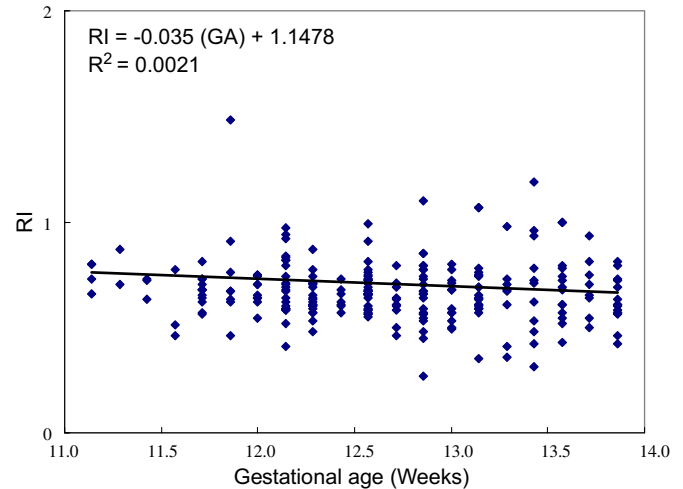


Fig. 5. Individual values for resistance index in the ductus venosus in normal pregnancy [RI =  $-0.035 \text{ (GA)} + 1.1478$ ,  $r = -0.064$ ,  $p = 0.468$ ]. GA = gestational age (wk); RI = resistance index.

a significant increase (Pearson's  $r = 0.155$ ,  $Pp = 0.013$ ) in D-wave with gestational ageGA (Table 1).

### 4. Discussion

Several studies have been published evaluating the DV Doppler waveforms in the first and early second trimesters of pregnancy, which have demonstrated an increase in the S-wave and D-wave during pregnancy. These findings on the DV velocity disclosed a decrease in cardiac afterload due to an increase in cardiac compliance, and a decrease in placental resistance during pregnancy. Teixeira and colleagues<sup>17</sup> examined hundreds of fetuses at the gestational ages between 10 and 14 weeks, describing an increase in the ductus venosus blood flow velocity with GA for the S-wave and D-wave. Prefumo and coworkers<sup>18</sup> performed a study of 198 fetuses between 10 and 14 weeks' gestation and reported an increase in mean blood flow velocity with increasing crown rump length (CRL) for the S-wave. Nevertheless, Montenegro and others<sup>19</sup> studied 61 fetuses at 10 to 13 weeks' gestation and did not observe an increase in DV blood flow velocities. One possible explanation for the contradictory results is that trophoblastic migration had not already occurred, so relevant modifications in fetal volemia and cardiac compliance could not be observed.<sup>19</sup>

Table 1  
Regression analysis and for S-wave, D-wave, and PIV.

Variable		<i>r</i> value	<i>p</i> value*
S-wave	$1.4214 \text{ (GA)} + 17.448$	0.09	0.154
D-wave	$1.4896 \text{ (GA)} - 7.1547$	0.155	0.013
PIV	$-0.0358 \text{ (GA)} + 1.4143$	-0.05	0.378
RI	$-0.035 \text{ (GA)} + 1.1478$	-0.064	0.468

D-wave = peak diastolic velocity; GA = gestational age (wk); PIV = pulsatility index for veins; RI = resistance index; S-wave = peak systolic velocity.

\*  $p < 0.05$  is significant.

Table 2  
Evaluation of ductus venosus flow.

Reference	Number of cases	Gestational age (weeks)	S-wave (cm/s)	D-wave (cm/s)	PIV	RI
Van Splunder, <sup>20</sup> 1996	262	8-20	↑	↑	↓	N
Montenegro, <sup>19</sup> 1997	61	10-13	I	I	N	N
Prefumo, <sup>18</sup> 2002	198	10-14	↑	N	↓	N
Teixeira, <sup>17</sup> 2008	843	10-14	↑	↑	↑/↓	N
This study	252	11-14	I (P=0.154)	↑ (P=0.013)	I (P=0.378)	I (P=0.468)

S-wave = peak systolic velocity; D-wave = peak diastolic velocity; PIV = pulsatility index for veins; ↑ = increased with gestational age; ↓ = decreased with gestational age; ↑/↓ = increased and then decreased with gestational age; I = independent; N = not evaluated.

Few reports concerning PIV are available in the literature. Van Splunder and colleagues<sup>20</sup> performed ductus venosus S-wave, D-wave, and PIV readings in 262 fetuses between 8 and 20 weeks. An increase in the S-wave and D-wave and a decrease in the PIV with GA were reported.<sup>20</sup> Prefumo and coworkers<sup>18</sup> reported a decrease in the PIV above a CRL of 38 mm, but the trend was not statistically significant. Teixeira and others<sup>17</sup> reported an increase in the PIV between 10 and 14 weeks. The authors thought the possible explanation was that trophoblastic migration does not occur until this GA. The absence of trophoblastic migration events might explain the high afterload and low blood flow velocity during atrial contraction, leading to a high PIV value in early gestation.<sup>17</sup>

An increase in the D-wave peak velocity was observed with advancing gestation, a similar results as in previous studies. When comparing our findings with previously published reports on DV flow measurements during the first and early second trimesters of normal pregnancy, some differences were observed between our values, and the values reported in other studies (Table 2).<sup>17–20</sup> First, we used the gestational week as a parameter instead of CRL, which enables our readers to more easily determine the relationship between DV and the gestational week. The gestational weeks of the cases in our study were quite compatible with CRL. We did not collect the data from the patients with possibly erroneous dating or equivocal fetal size. Hence, the gestational age was representative of fetal size. Second, the trend of RI was not discussed in previous studies. But in the Taiwanese population (southeast Asia), a decreasing RI tendency with GA was noticed. Although the S-wave peak velocity showed an increasing trend, and the PIV and RI showed a decreasing trend, they did not reach statistical significance in our study. One possible explanation is the narrow gestational interval. Our study group was between 11 and 13 + 6 weeks' gestation, most being from 12 to 13 + 6 weeks, and this period is narrower than the previous reports. Thus, there was an absence of important changes in volume flow, cardiac compliance, or stroke volume during 11 to 13 + 6 weeks' gestation. As previous studies have claimed, the onset of trophoblastic migration could begin or not occur in this period, making the hemodynamic changes not remarkable. Consequently, the blood flow velocity and the PIV were not strongly associated with the GA at the time. Besides, fetuses in this stage experience an important change in the development of organs and body mass. Therefore, the diastolic velocity seems to increase more significantly than the systolic velocity, which would

support more nutrition for the fetal development, like the change of umbilical artery with gestational age. Consequently, we detected a significant increase in the D-wave velocity.

There were some limitations of our study. First, the number of cases examined was not sufficient to draw the "reference curve" of DV of the Taiwanese population. Second, we only collected a few abnormal fetuses (such as intrauterine growth restriction (IUGR) and preeclampsia; data not shown in this paper), which made it difficult for us to compare the differences between the normal and the abnormal groups.

In conclusion, DV Doppler velocimetry is a good and important tool to assess fetal hemodynamics in the first and early second trimesters of pregnancy. In our research group, further studies with a larger number of cases and longer range of GA are ongoing to confirm the results presented here and establish the reference range for the Chinese population (Taiwanese). Abnormal pregnancy cases should be continuously collected by our research team, and verifying the potential contribution of these indices for diagnosed pregnancies at high risk at different gestational ages may be explored in the future.

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